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Nuclear Division

OAK RIDGE Y-12 PLANT

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SURVEY OF THE FLY-ASH DISPOSAL SYSTEM AT THE OAK RIDGE Y-12 PLANT

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ABSTRACT

A survey was made of the Y-12 Steam Plant fly-ash disposal system. As a result of this study, corrective antipollution measures were initiated to prevent the influx of some buoyant, low-density, spherical fly-ash particulates into Melton Hill Lake.

CONTENTS

SUMMARY

A survey was made of the fly-ash disposal system for the Steam Plant of the Oak Ridge Y-12 Plant.[a] A normal overflow channel has been provided at the south side of an earthen fly-ash retention basin, also a dam has been constructed which directs the ash to a water-filled quarry. Although most of the fly ash sinks in the quarry, a small percentage floats as a surface scum deposit, and some has previously reached Melton Hill Lake. Laboratory studies have identified the surface deposit as hollow, spherical, microspheres of fly ash. Corrective measures have been initiated to impound the buoyant fly-ash microspheres at a floating-log barrier located at the clear-water discharge end of the water-filled quarry.

(a) Operated by the Union Carbide Corporation's Nuclear Division for the US Atomic Energy Commission.

INTRODUCTION

Fly ash is the product of combustion that results from the burning of pulverized coal in steam plant and power boiler operations. As the coal is burned, the fly ash is formed from the noncombustible components in the coal and from the incomplete combustion of coal particles that occurs in the furnace. Microscopic examination of fly ash shows it to consist of particles ranging in size from 1 to 300 microns in diameter and having a wide variation in shape, color, and texture. It has been estimated(1) that, in 1970, the output of fly ash from various electrical utilities in the United States will reach 30 million tons. Thus, the disposal of this fly ash poses a serious economic and aesthetic problem.

Fly ash that is generated at the Y-12 Steam Plant is currently mixed with water and pumped as a slurry over the crest of Chestnut Ridge, located at the south perimeter of the Plant, where it flows by gravity to an excavated earthen retention basin and dam. However, the ash and sluice water now overflow through a normal channel at the retention basin and into an abandoned, water-filled limestone quarry.

Although most of the fly-ash solids settle in the quarry, some of the particulates are buoyant and remain suspended on the surface of the quarry, forming a gray scum which may overflow into a lagoon at Melton Hill Lake. An investigation was inititated to study the buoyant type of fly-ash solids entering the lake area and to study possible remedial measures to be applied, based on laboratory and engineering considerations.

Previous studies on the general fly-ash removal and storage system in use at Y-12 were made by Pokela(2) and the General Engineering Division of the Oak Ridge National Laboratory(3) with regard to the adequacy of the storage volume, but no previous investigation has been made of the problems associated with the buoyant type of fly-ash contaminants entering Melton Hill Lake.

SURVEY OF THE FLY-ASH DISPOSAL SYSTEM

EXPERIMENTAL STUDIES

Sample Collection

A survey was made of the fly-ash retention basin and dam at Chestnut Ridge, the water-filled quarry, the ground area below the quarry, and the runoff into the Canoe Club lagoon at Melton Hill Lake to assess the degree of particulate contamination and to obtain samples for analytical evaluation at these various locations.

Samples of the dry fly ash and fly-ash solids at the input to the quarry, at the quarry outlet, and at the lagoon inlet to Melton Hill Lake were obtained for evaluation by the methods of photomicrography, particle-size distribution, X-ray radiography, and X-ray diffraction. A summary of the results by carbon analyses, particle-size distribution studies, and spectrographic analyses of the dry fly-ash solids is given in Table 1.

Photomicrograph and Radiograph Studies

Photomicrographs showing the particle size and shape of the fly-ash solids samples at the inlet and outlet portions of the quarry are given in Figure 1. From Figure 1, it can be seen that the fly-ash solids which enter the water-filled quarry are irregularly shaped, dense particulates, while those sampled at the outlet end of the water-filled quarry are semitranslucent and spherical in shape, less dense, and actually float on the surface of the water as a surface scum. X-ray radiographs of the fly-ash solids sampled at the quarry outlet, as seen in Figure 2, show that the fly-ash particulates are spherical, quite uniform in size, and hollow. X-ray diffraction analyses of these hollow fly-ash microspheres showed that an alumina-silica complex ($2Al_2O_3 \cdot 2SiO_2$) is the major constituent, with no other detectable intermediate or minor constituents present.

Figure 3 is a photomicrograph showing the buoyancy and general uniformity of size of the semitranslucent, low-density, fly-ash particles and some intermixed black, irregularly shaped particles. Both comprise the surface layer floating on the water in a glass dish. The black, irregularly shaped particles shown in Figure 3 appear to be incompletely burned coal particles, which would account for the relatively high carbon content normally associated with the fly ash reported in Table 1.

Table 1

ANALYSES OF DRY FLY-ASH SOLIDS FROM THE Y-12 STEAM PLANT

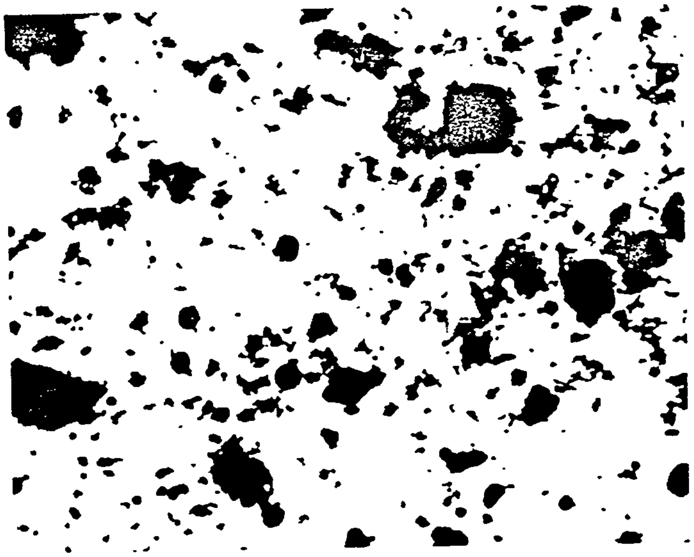
Test	Sample A	Sample B	Sample C
Carbon (%)	12.08	11.94	12.51
Toluene Density (gms/cc)	2.09	-	-
Particle-Size Distribution(1)			
Diameter (μ)	Percent Less than Given Diameter (wt %)		
125.0	100	-	-
69.0	90	-	-
35.6	75	-	-
12.1	50	-	-
6.6	25	-	-
4.1	10	-	-
1.0	0	-	-
Spectrographic (all values in %)(2)			
Element			
Aluminum	> 20	20	18
Barium	0.12	0.12	0.10
Boron	0.03	0.05	0.05
Calcium	0.6	0.6	0.6
Chromium	0.03	0.03	0.03
Copper	0.02	0.03	0.03
Iron	10	10	7
Lead	0.01	< 0.01	< 0.01
Lithium	0.04	0.08	0.08
Magnesium	0.6	1.0	0.9
Manganese	0.04	0.04	0.08
Nickel	0.02	0.03	0.03
Potassium	-	3	2.5
Silicon	20	35	30
Sodium	0.6	0.7	0.6
Titanium	0.3	1.0	0.8
Vanadium	0.03	0.04	0.08

(1) By micromerograph analysis.
(2) All other elements present in quantities less than their detectable limits.

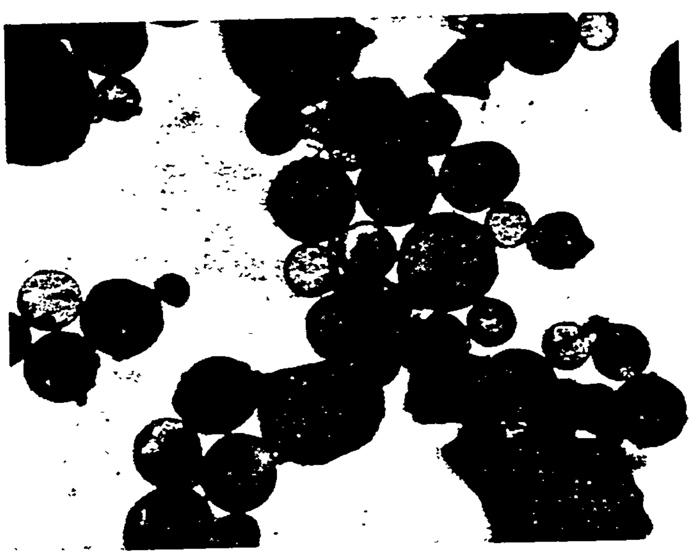
A photomicrograph showing the spherical shape of some of the dry fly-ash particulates found overcoating the ground area at the inlet lagoon of Melton Hill Lake is presented in Figure 4. From this photograph it can be seen that this gray deposit of contamination consists, predominantly, of fly-ash microspheres. Thus, it appears that during periods of heavy rainfall, these ground surface deposits are washed out into the lake area to produce additional water surface scum.

Area Views

A photograph showing the north side of the quarry where the fly ash enters is presented in Figure 5; a photographic view of the south side of the water-filled

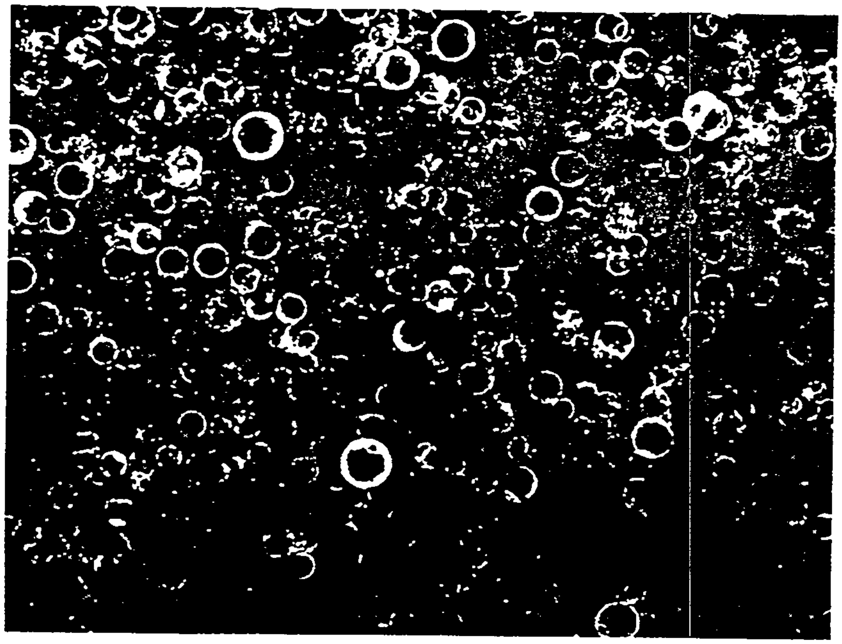


(a) Inlet to Quarry

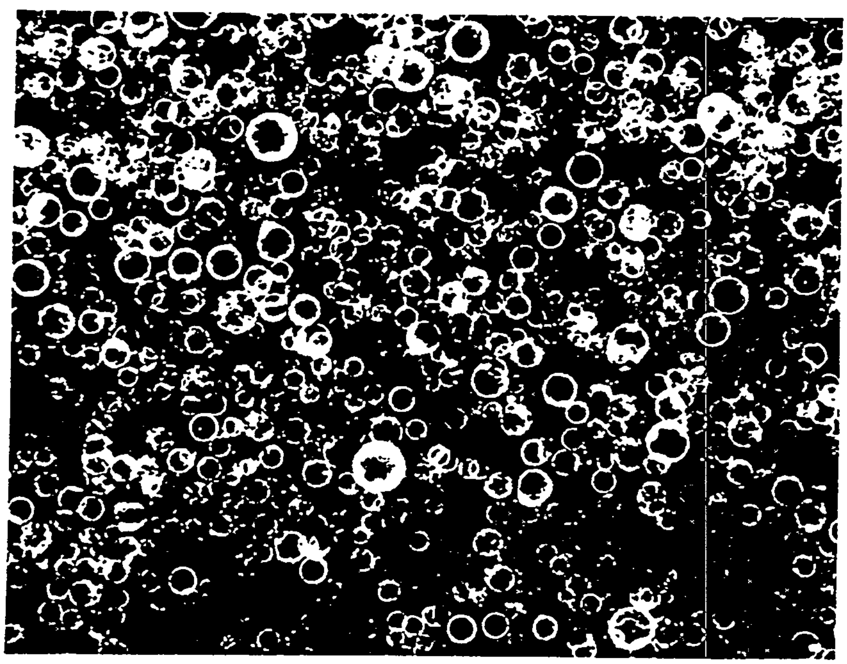


(b) At Quarry Outlet 130872

Figure 1. PHOTOMICROGRAPHS OF FLY-ASH SOLIDS AT THE QUARRY. (95X)



(a) Low Illumination



(b) High Illumination 130871

Figure 2. X-RAY MICRORADIOGRAPHS OF BUOYANT FLY-ASH SPHERES SAMPLED AT THE QUARRY OUTLET. (20X)

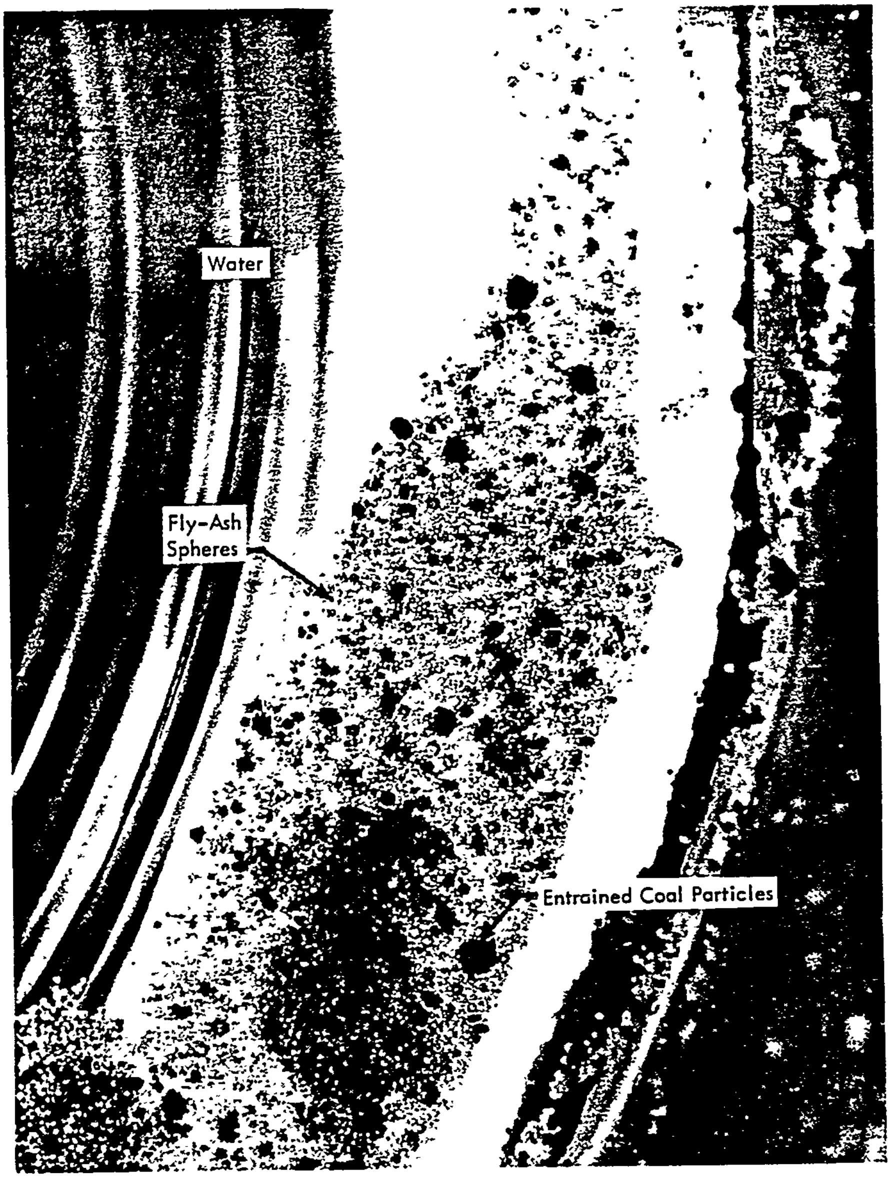


Figure 3. PHOTOMICROGAPHS OF SOME HOLLOW FLY-ASH MICROSPHERES FLOATING ON WATER IN A GLASS DISH. (Bright Field Illumination; 9X)

quarry is given in Figure 6. In Figure 6, a layer of the buoyant fly-ash particles which are floating as a gray scum on the surface of the water is readily apparent at the lower left corner of the photograph. These buoyant particles eventually drift across the quarry and should be retained by the floating-log barrier located at the southwest corner of the quarry where the overflow water discharges into an underground culvert beneath a nearby road.

Figure 7 shows that the buoyant fly-ash particles are still floating as a layer of scum on the surface of the Canoe Club lagoon of Melton Hill Lake. Photographs

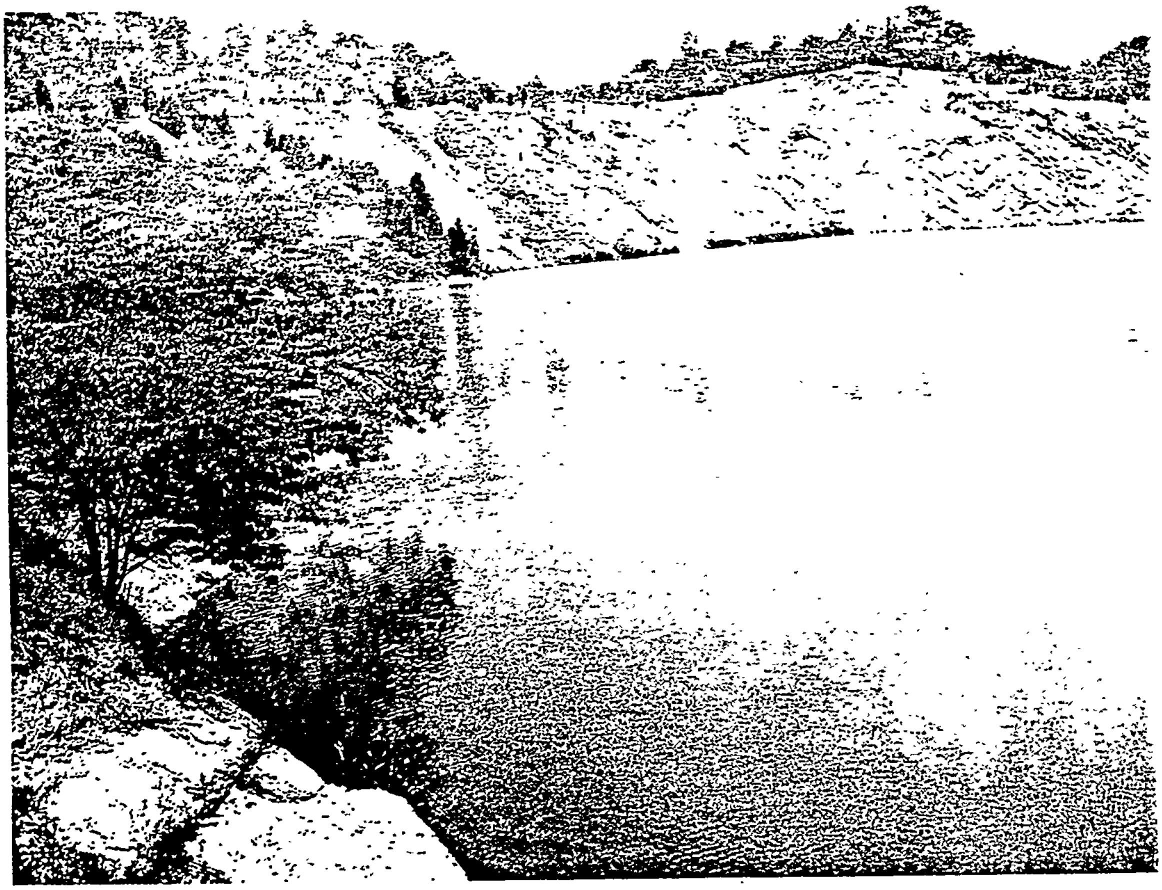


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Figure 5. ACROSS-POND VIEW OF THE INLET TO THE WATER-FILLED QUARRY.

Some preliminary laboratory tests were made on various methods designed to coagulate, cement, or agglomerate the hollow fly-ash microspheres together into a single coherent mass which would allow it to be subsequently sunk, but these were investigated only as possible backup measures to be employed in the event that simple mechanical containment at the quarry proved to be ineffective.

DISCUSSION

A map showing the general location and major features of the fly-ash disposal system is given in Figure 10. A view of the fly-ash/water-slurry pipeline from the Steam Plant as it goes over Chestnut Ridge is shown in Figure 11. The fly-ash retention basin area on Chestnut Ridge can be seen in Figure 12. This basin covers approximately 20 acres and was completed in 1955.[2] When the retention basin becomes partially filled, the fly ash and sluice water overflows through a normal channel along the McCoy Branch and meanders for about one-half mile through woods and pastureland to the quarry. The

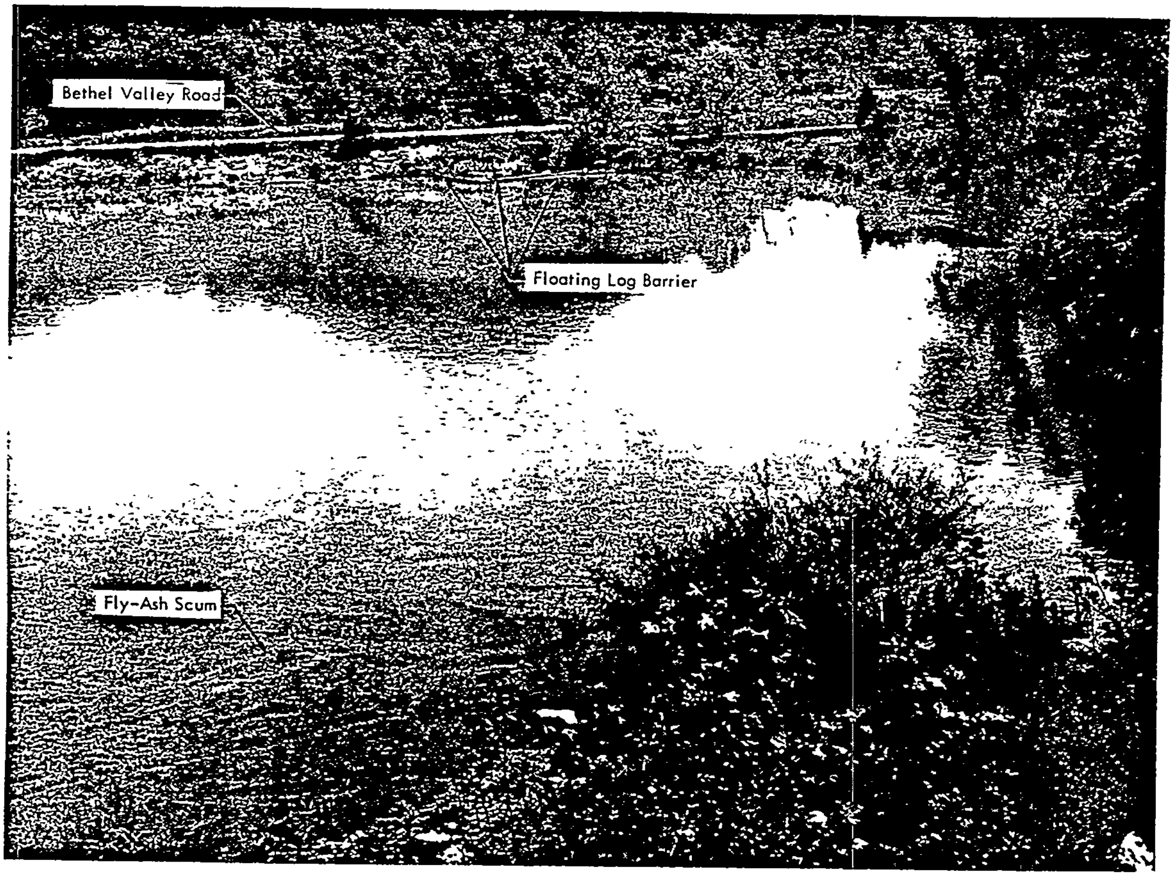

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Figure 6. ACROSS-POND VIEW OF THE OUTLET FOR THE WATER-FILLED QUARRY. (Note Fly-Ash Scum Near the Inlet to the Quarry)

discharge channel, lined with gray fly-ash solids at the south side of the retention basin, is seen in Figure 13.

The Y-12 Steam Plant generates approximately 100,000 pounds of steam per hour in the summer and approximately 600,000 pounds per hour in the winter.(4) At the winter steam rate, assuming that one pound of coal is required per ten pounds of steam generated and that there is an average ash content of 15 percent for the coal, it may be calculated that 1,500 pounds of fly ash per hour or approximately 0.75 ton per hour will accumulate. Thus, at the winter rate:

is this correct! ?

$$\frac{600,000 \text{ lbs steam}}{\text{hour}} \times \frac{\boxed{1 \text{ lb coal}}}{10 \text{ lbs steam}} \times \frac{15 \text{ lbs fly ash}}{100 \text{ lbs coal}} = 9,000 \text{ lbs fly ash/hr or } 4.5 \text{ tons/hr, or}$$

coal per hr

$$4.5 \text{ tons/hr} \times 24 \text{ hrs} = 108 \text{ tons/day.}$$

Similarly, it may be calculated that at the summer steam rate of 100,000 pounds of steam per hour, 18 tons of fly ash per day will accumulate for disposal.

130853

Figure 7. LAGOON INLET TO THE MELTON HILL LAKE RECREATIONAL AREA SHOWING THE SURFACE SCUM OF BUOYANT FLY-ASH PARTICLES.

Admittedly, the percentage of buoyant, hollow, fly-ash spheres present in the fly ash is small; however, even at the lower summer steam rate, assuming the buoyant fly-ash particulates comprise only 0.1 percent of the total ash generated, the amount of buoyant fly-ash particles that could be carried into Melton Hill Lake would be 36 pounds per day. Since this material has a low bulk density, daily accumulations of this fly ash in the lake could soon result in a scum on the surface of the water of considerable magnitude.

Previous calculations by Pokela[2] indicate that the abandoned water-filled quarry will provide approximately 50 years or more of storage capacity for the Y-12 Plant fly ash at the present rate of ash accumulation. Although fly-ash solids are being carried along a channel at the top of Chestnut Ridge downstream along the McCoy Branch through woods and pastureland to the quarry, this path does not appear to be objectionable because of the remote location of the terrain to the quarry, as was concluded in a previous fly-ash disposal study made in 1968.[3] In this previous study, the presence of some

130854

Figure 8. CANOE CLUB LAGOON AREA OF MELTON HILL LAKE.

small, buoyant, particulate matter in the fly ash at the quarry had been observed; but, at that time, it did not appear to present any serious surface contamination problem at Melton Hill Lake.

During the spring of 1969, however, equipment and operational modifications were made at the Steam Plant which were believed to have greatly increased the relative amount of buoyant particulates associated with the fly ash. As reported by the US Atomic Energy Commission in June 1969:(5) "All four of the coal-fired boilers at the Y-12 steam generating facility have now been equipped with improved air-pollution control devices known as electrostatic precipitators. These high-efficiency precipitators are designed to remove up to 98 percent of the fly ash and other particles from smoke discharged into the atmosphere from the Steam Plant's two stacks. The cost of the equipment and its installation was about $881,000. The precipitators replaced mechanical dust collectors built into the boiler systems for pollution control when the Steam Plant was constructed in 1954. Rust Engineering Company, AEC's prime construction contractor in Oak Ridge, installed the devices."

130861

Figure 9. RECREATIONAL AREA OF MELTON HILL LAKE.

Thus, prior to 1969 it is believed that a relatively large amount of the hollow, lightweight, low-density, spherical, fly-ash particulates were probably discharged into the atmosphere by the two stacks at the Steam Plant. Since the electrostatic precipitators were installed and operated, however, a considerably greater amount of these low-density, spherical, fly-ash particulates is being precipitated at the stacks and collected with the other fly-ash particles and pumped as a slurry to the Y-12 ash disposal system facilities. Thus, due to the buoyant nature of these spherical particulates, relatively larger quantities could have by passed the existing floating-log barrier at the quarry and been discharged into Melton Hill Lake.

Recently, chemical stabilization(6) has been used as a method for reacting various mine, mill, and smelter wastes. A reagent is employed to form a water and air-resistant crust or layer. Among the materials commonly used are sodium silicates with varying silicon dioxide-to-sodium oxide ratios, sodium silicate with iron(II) sulfate and calcium chloride additives, lime, various

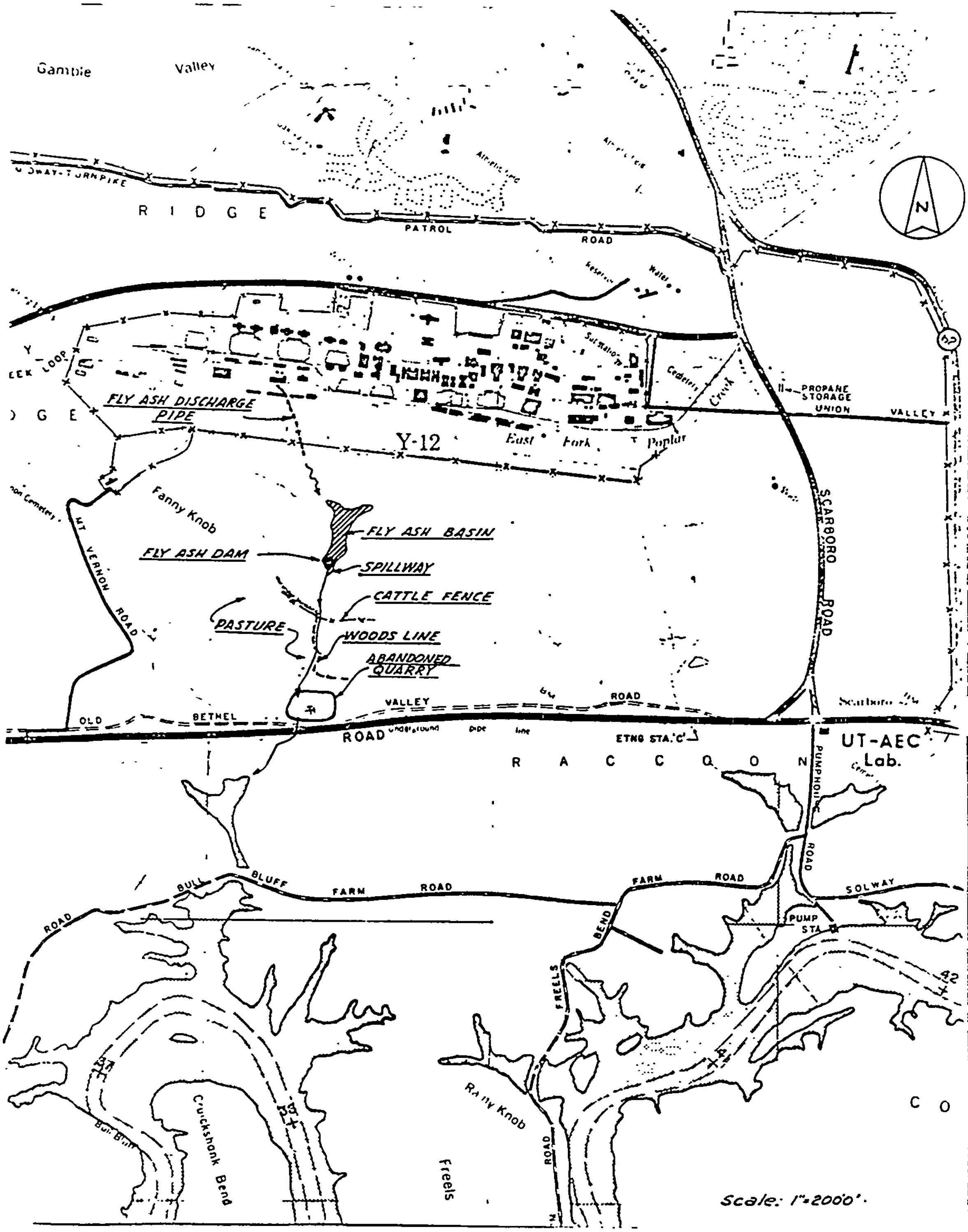

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Figure 10. MAP SHOWING LOCATION OF Y-12 FLY-ASH DISPOSAL SYSTEM.

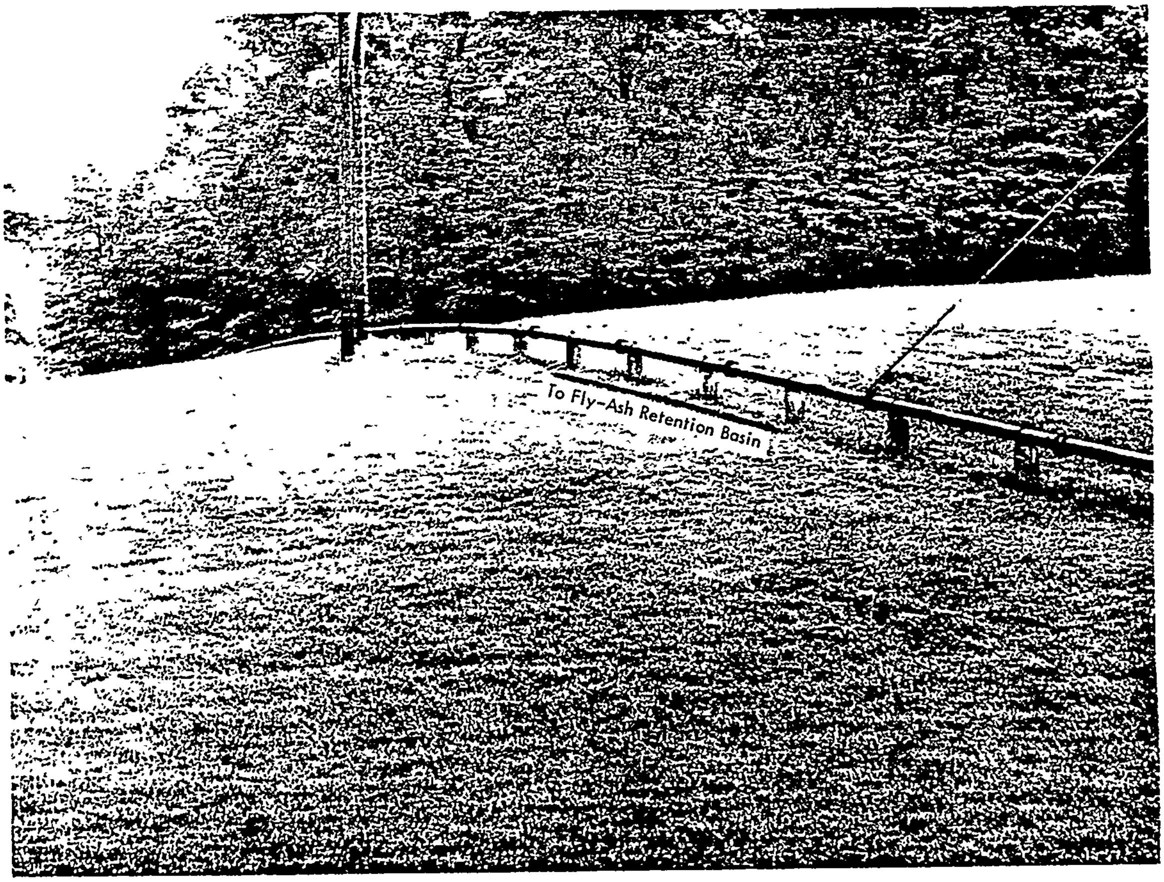

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Figure 11. FLY-ASH/WATER SLURRY PIPELINE FROM THE Y-12 STEAM PLANT.

lignin sulfonates, bituminous base products, elastomeric polymers, and resinous adhesives. Inasmuch as some of these chemical additives could result in undesirable chemical changes in the quality of water overflowing the quarry into Melton Hill Lake (such as a change in pH), it was not deemed advisable to investigate the use of such additives at the present time. However, if the mechanical containment measures which were recently initiated by the Y-12 Utilities Department at the floating-log barrier should prove to be ineffective, then additional development studies on chemical stabilization, skimming and mechanical pulverizing, or the installation of an outlet pipe several feet below the water surface may be necessary.

The same type of spherical fly-ash particulates found in the Y-12 Steam Plant fly ash has been named "pfa",[b] and the mechanism of formation has recently

(b) Pfa - pulverised fuel ash. The floatable portion is called cenospheres.[8]

130852

Figure 12. FLY-ASH RETENTION BASIN ON CHESTNUT RIDGE.

been described in a British publication:(7) "Pfa is a fine powder, usually of a light gray or brown color, but sometimes much darker. It consists largely of tiny spheres of silicate glasses. Infrared analyses reveal that they contain trapped carbon dioxide with only traces of other gases. It appears that pfa spheres are inflated by the relatively slow oxidation of carbides dissolved in the fused silicate. The carbide is apparently formed from carbon in contact with the outer surface of the fused silicate particle. There are other processes which could result in hollow spheres, but only that based on carbides seems to fit the temperature history of particles in coal-fired furnaces."

130858

Figure 13. SOUTH SIDE OF THE FLY-ASH RETENTION BASIN SHOWING THE DISCHARGE CHANNEL.

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